display presentation by some tens of milliseconds. In this case, the prime is understood to involve an anticipatory response in higher cortical mechanisms, which serves to "preactivate" lower level prime- and target-coding mechanisms.

Evidence for multiregional prime activity with particular temporal characteristics may also be drawn from examination of the EEG[1] accompanying priming-stimulus presentation. Component activations reconstructed from the EEG provide evidence for prime development as the combined function of occipito-parietal and prefrontal cortical activation. This is shown in Figure 1. Here component activity consists of coactive neural assemblies located under electrodes Fp1 and O1/P3. One function of prefrontal cortex is a delayed sample to matching response and it seems likely that the coactivation necessary for coding repeated prime presentation, in terms of the global frequency of priming-stimulus presentation, might be carried out by assemblies under Fp1 responding to a staccato of 10-Hz signals from posterior assemblies coding the local spatio-temporal organization of the priming display. Of particular interest is the timing of the oscillatory response to priming-display presentation. Notice in Figure 1(c), at the intersection of horizontal traces of high frequency (35 and 62 Hz) activity within the time period of maximum variation lie on, or just after a brief loss of coherence and prior to a subsequent burst of coherent oscillatory activity. From ontogenesis $>$ 66 Hz at 400 msec, coherence spreads across lower frequencies as a function of time. Related activity occurs in the 35–40-Hz region at around 530–540 msec with corresponding activity at around 10 Hz at 590 msec, almost immediately prior to target-display presentation at 600 msec. The pattern of coactivation between neural assemblies under Fp1 and O2/P3 thus offers itself as a strong candidate for generation of the anticipatory response reported by Kompass and Elliott (2001).

Two points emerge from the analyses presented here. The first is that prefrontal-posterior synchronization appears to be involved in the formation of stimulus-related persistence, which has been shown to possess a duration sufficiently short to suggest that coactive neural assemblies may remain functional for as little as 200–300 msec post-stimulus offset (Elliott & Müller 2000). The second is that at least one characteristic of the prime response, the temporal precession of prime activity relative to target display presentation, may emerge as a function of cascading fluctuations in coherence between various frequency responses to prime stimulus presentation. An identification of particular dynamic states, which appear to be related to particular psychophysical performance, refocuses attention towards the requirement for description of active cognitive states in terms of the dynamic states upon which they may depend.

NOTE

1. For 12 subjects (4 male, mean age 24.1 years) the EEG was recorded from 19 Ag-AgCl electrodes (electrode positions are shown in Figure 1[a]) according to the international 10–20 system. Subjects performed a variant of the primed target detection task described in Elliott and Müller (1998). The experiment described here employed a priming-display presentation frequency of 40 Hz while priming displays were presented for 600 msec and followed immediately by target-display presentation. The electrodes were mounted in an elastic cap, were referenced to Fz while the nose served as the ground electrode. Electrode impedance was maintained below 5 kOhm. Horizontal and vertical electrooculargrams (EOG) were additionally registered with four electrodes. EEG activity was amplified by means of NeuroScan amplifiers, digitized on-line with a sampling rate of 500 Hz and analog-filtered with a 0.1-Hz high-pass and a 100-Hz low-pass filter. A 50-Hz notch filter was applied to remove artifacts related to the main's electricity supply.

For the recording of EOG, the time constant 300 msec with a low pass filter at 70 Hz was used. The EOG-channel was visually inspected for each trial, and trials with eye movement or blink artifact were rejected. Localized muscle artefacts (at electrodes T3 and T4) were identified and if present reconstructed by means of an extended independent components analysis (ICA) algorithm (see Makeig et al. 1999). Averaging epochs lasted from termination of an alerting tone 200 msec before until 1,200 msec after priming-display presentation. Baselines were computed in the – 200 to 0 msec interval for each trial and subtracted prior to subsequent analyses. Analyses were carried out on the averaged event-related potential (ERP) for each subject.

In a first step, a series of component activations were recovered from each averaged signal by means of ICA using information maximization (infomax) techniques described by Bell and Sejnowski (1995) with variants of the ICA Matlab package (v.3.52) (available at: http://www.cnl.salk.edu/~scott/). In order to classify components and identify particular groups of clusters that appeared during premask-matrix presentation, components were defined in terms of the latency and topographical distribution of variance maxima (in this case, topographical projections were standardized by substituting raw activation at each electrode with the corresponding z-value computed relative to all projected activations at the time of maximal activation). Classification then proceeded by means of cluster analysis, calculating Euclidean distance between objects and computing linkages in a hierarchical cluster tree based upon the average distances between groups of objects and a threshold of 19 clusters (cophonetic correlation coefficient $c = 0.81$). The resulting clusters were considered for further analysis if (i) they included activations from more than 75% of subjects (i.e., 9 or more of 12 activations), (ii) they were specific to priming-stimulus presentation, (iii) maxima fell within the period of priming-display presentation, and (iv) if, following examination of the frequency component of each component activation by means of a 256-point fast-Fourier transform (FFT), strong peaks were evident at, or close to the priming-display presentation frequency of 40 Hz. On these criteria, a single component cluster was identified, which is described in Figure 1 and the main body of text.

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Thoughts from the long-term memory chair

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Abstract: With reference to Ruchkins et al.'s framework, this commentary briefly considers the history of working memory, and whether, heuristically, this is a useful concept. A neuropsychologically motivated critique is offered, specifically with regard to the recent trend for working-memory researchers to conceptualise this capacity more as a process than as a set of distinct task-specific stores.

In this interesting article, Ruchkin and colleagues tackle the important question of whether working memory reflects the activation of long-term memory. They advance a parsimonious "activation-proceduralist" framework, in which they specify that long-term memory systems associated with posterior cortical regions provide the necessary representational basis for working memory, and that the prefrontal cortex provides the necessary attentional control. In so doing, the authors argue that there is no reason to propose the existence of specialized neural systems whose functions are limited to short-term memory buffers, and they raise related and important issues concerning whether working memory is itself a useful concept. This is an ancient and significant debate. William James (1890) drew the distinction between primary and secondary memory, regarding the former as the "rearward portion of the present space of time" as distinct from the "genuine past." Later, in the second half of the twentieth century, it was suggested that the short-term store might use phonological coding (as indicated, e.g., by Conrad's phonological confusability effect), whereas long-term memory may be mediated primarily via semantic coding.

In their article, Ruchkin et al. themselves evoke findings and concepts, which, as the authors acknowledge, hark back to some ideas that were articulated several years ago; for example, those proposed by Crowder (1993). Indeed, the influence of what could be termed the "international working-memory lobby" notwith-

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standing, one may wonder to what extent Ruchkin and colleagues are targeting something of a straw man here. For example, in recent years there has been a trend for working-memory researchers themselves to conceptualise this capacity more as a process than a set of distinct task-specific stores. These researchers have raised important questions regarding the role of rehearsal in transferring mnemonic information from short-term memory (STM) to long-term memory (LTM), and to observed temporally-mediated differences in the recency effect of serial recall. Furthermore, the distinction between phonological (STM) and semantic (LTM) processing has been challenged by consideration of the processes underlying capacities such as sentence comprehension.

From a different perspective, Ruchkin et al.'s neurologically informed analysis is timely; that is to say, it agrees with some contemporary evaluations of the functional properties of working memory offered by cognitive researchers such as Gordon Brown (cf. Brown 2002; Brown et al. 2000; Neath et al. 1999), as well as by neuropsychological researchers, including Morris Moscovitch and Gordon Winocur (the latter articulating concepts such as "working with memory" in the 1990s; cf. Moscovitch & Winocur 2001). It has been suggested by some recent cognitive researchers, for example, that the demonstration of a working-memory recency effect occurring across different time spans relates to the use of working-memory "scanning," which depends (at least in part) on the exact relationship between items of target information and the background from which they must be discriminated.

Ruchkin et al. raise an important point regarding the claim by Baddeley (2001a) that construing short-term memory as activated long-term memory is inconsistent with neuropsychological data. Furthermore, patients may also show dissociations within the domain of STM; that is, there are demonstrated selective cases of impaired verbal versus visuospatial STM (Basso et al. 1982; Hanley et al. 1991).

There is also some evidence that visual (as distinct from visuospatial) STM can also be selectively impaired (e.g., Davidoff & Ostergaard 1984; Warrington & Rabin 1971), and that phonological and lexical STM deficits may be separable (Martin et al. 1994).

Long-term memory is sometimes preserved in these individuals with STM deficits (e.g., in Warrington & Shallice's (1969) patient, KF, with selective auditory verbal STM loss). Indeed, this is the kind of evidence that has been adduced by researchers such as Baddeley (2001a). However, consistent with the views articulated by Ruchkin et al., the widely held view regarding selective STM loss in some neuropsychological patients has been called into question in situations in which the STM and LTM tests tap into the same type of information (e.g., Baddeley et al. 1988; Hanley et al. 1991), with suggestions that there is, in fact, evidence of serial processing from STM to LTM. Mayes (2000) argues that LTM probably is only selectively preserved when it taps different information from that affected by a STM disorder.

The views articulated by Ruchkin et al. offer significant heuristic value. Indeed, as indicated in the previous paragraph, what may now be emerging in the memory literature is the breakdown of the old primary-STM-WM/secondary-LTM distinction, with an emphasis instead on *function* and *process* (see, e.g., Toth & Hunt 1999; "Not one versus many, but zero versus any"). On a related theme, Roediger et al. (1999) have articulated a component-processing framework of memory, whereas Gordon Brown (personal communication) has provided considerable food for thought in recent years by modelling the diversity of memory phenomena in terms of potentially common processes across previous structural divisions. In conjunction with Gordon Brown, my colleagues and I working in Western Australia have demonstrated that working-memory capacity may also be affected in a selective hippocampal patient with profound long-term memory deficits. More specifically, this patient's poor performance on the primacy portion of serial recall appears to be a result of the fact that (in contrast to controls) he does not rehearse items in working memory when he is encouraged to do so. This may be an informative observation with respect to the framework articulated by Ruchkin et al.

There are some elements of the framework proposed by Ruchkin et al. in which further information would have been useful in order to evaluate the model's explanatory value. For example, when stating that "long-term memory systems in posterior cortex are initially activated for the processing of incoming information" (target article, sect. 5, para. 1), it would be useful to know explicitly whether these LTM systems are deemed to be semantic systems, episodic systems, or both. Or, indeed, whether a systems framework is embraced at all by the authors, and, if so, which one? (See Foster & Jelicic 1999, for a discussion of this complex question.) On the related theme of memory systems, to what extent are implicit, as distinct from explicit, memory representations drawn upon in mediating working-memory processes, according to this framework? Ruchkin and colleagues further state that "as stimuli are perceived and processed in posterior cortex, long-term memory codes are activated" (sect. 5, para. 2). Yet, there is considerable ongoing debate in the literature regarding the representational nature of these LTM codes.

More specifically, there is currently substantial debate regarding the significance of context in the neural representation of established memories. It would have been useful to know whether this is a relevant consideration for the kinds of posterior memory systems that are specified by Ruchkin and colleagues. On a related note, to what extent is the medial temporal lobe memory system deemed relevant in this model? The authors state,

> the neural systems that ultimately become the repositories of the consolidated long-term episodic memory for the novel information are initially active, with the hippocampus providing coordinate control. In this view, short-term episodic memory consists of well-consolidated and partially consolidated long-term episodic memories in an active state.

Yet, according to the conventional consolidation hypothesis, memories are "downloaded" from the hippocampus to the neocortex over time. If the hippocampus is considered relevant for the Ruchkin et al. framework, as appears to be the case, to what extent would it be possible to identify the involvement of this circumscribed brain region using an ERP methodology, given some of the localization issues that the authors themselves identify in the Appendix? To what extent, in this framework, is attention considered to be related to or distinct from memory rehearsal processes, specifically regarding the proposed role of the prefrontal cortex in subserving "attentional control." Are prefrontally-mediated mechanisms the only factors of consideration when evaluating the basis of short-term memory *capacity*, or may posterior cortical constraints be relevant as well (i.e., aside from those matters relating to working-memory decay specified by Ruchkin et al.). The authors state, "Recall and maintenance of episodic information involves activation of the binding circuitry; retention of novel episodic information involves the operation of binding formation and the initial consolidation process" (sect. 1.3). However, the significance of these statements is unclear as written, and further elaboration is required.

Missing the syntactic piece

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Abstract: The notion that the working-memory system is not to be located in the prefrontal cortex, but rather constituted by the interplay between temporal and frontal areas, is of some attraction. However, at least for the domain of sentence comprehension, this perspective is promoted on the basis of sparse data. For this domain, the authors not only missed out on the chance to systematically integrate event-related brain potential (ERP) and neuroimaging data when interpreting their own findings on semantic aspects of working memory, but also neglected syntactic aspects of working memory and computation altogether.